

TES4 105 230 - N1-0002

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205522

U.S. ENVIRONMENTAL PROTECTION AGENCY  
TECHNICAL ENFORCEMENT SUPPORT AT  
HAZARDOUS WASTE SITES

TES IV  
CONTRACT NO. 68-01-7351  
WORK ASSIGNMENT NO. 230

ORMET CORPORATION PLANT  
MONROE COUNTY, OHIO  
  
PRELIMINARY ENDANGERMENT ASSESSMENT  
  
EPA REGION V

JACOBS ENGINEERING GROUP INC.  
PROJECT NUMBER: 05-B230-00

SEPTEMBER 1987

Submitted to:

Jacobs Engineering Group, Inc.  
222 S. Riverside Plaza  
Suite 1870  
Chicago, IL 60606

Attention: Regional Manager (Region V), D. Geers (3 copies)

TR-913-17A

ENDANGERMENT ASSESSMENT FOR THE ORMET  
CORPORATION PLANT

Preliminary Endangerment Assessment

Prepared Under

Program No. 1462

for

Subcontract No. 05-A005-S-87-0006

Under

Contract No. 68-01-7351

for

ICAIR Work Assignment No. 071462

JEG Work Assignment No. 230

Contact: Mr. Jeffrey S. Heaton

Telephone: (216) 464-3291

September 11, 1987

## FOREWORD

This Endangerment Assessment Document was prepared by ICAIR, Life Systems, Inc., under Subcontract No. 05-A005-S-87-0006 to Jacobs Engineering Group, Inc. This program was directed by Mr. Jeffrey Heaton and Ms. Jo Ann Duchene. The document was authored by Dr. Peter McCall and Dr. Gerald Matisoff, Case-Western Reserve University. Mr. Michael Kangas of ICAIR provided technical support and review.

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## EXECUTIVE SUMMARY

On-site storage of spent cathode material and scrubber sludge wastes at the Ormet Corporation plant has resulted in soil and ground-water contamination. Extensive well pumping has induced aquifer recharge from the Ohio River and may have introduced river borne contaminants into the aquifer.

The Ormet Corporation is located in Ohio on the inside of a meander in the Ohio River. The plant reduces alumina to aluminum metal. The site now contains a construction material scrap dump pile, five holding ponds, two areas formerly containing above ground piles of potliner wastes and three carbon sludge piles all in an area northwest of the production facilities. This 50-acre area is the potential source of contamination.

From the contaminants of concern detected at the site, ten indicator chemicals were selected to represent those chemicals that pose the greatest potential health risk at the site. They include chromium, copper, cyanide, fluoride, phenol and polycyclic aromatic hydrocarbons (PAHs).

Three complete exposure pathways were identified and quantified to analyze potential endangerment to human health. They are:

- Future on-site ingestion of contaminated drinking water
- Ingestion and/or contact with Ohio River water downstream of the plant
- Direct contact with on-site soils in the area used for past disposals

In the absence of rigorous quantitative risk assessments, contaminant risk is evaluated in two ways. First, the exposure point concentrations are compared to applicable or relevant and appropriate requirements (drinking water MCLs, Ambient Water Criteria, Ohio River Criteria). In any instance where the ratio of exposure level to acceptable level exceeds unity, the exposure level is unacceptable. Chromium and fluoride concentrations in ground water are at unacceptable levels when compared to the drinking water MCLs; Ohio River water concentrations of chromium, copper, cyanide, phenol and PAHs are at unacceptable levels.

Second, contaminant risk is evaluated by comparing chronic and subchronic intakes calculated from exposure point concentrations to standard intake values. A total hazard index is calculated for each pathway. If the hazard index exceeds unity, there may be a concern for a potential health risk.

The subchronic hazard index for on-site ground-water ingestion is 1.15; the chronic index is 65.5. All other hazard indices are below 1.0.

In the case of the carcinogenic PAHs upper-bound lifetime cancer risks were calculated for each exposure route. From ground-water ingestion, the total PAH risk is  $5.5 \times 10^{-2}$ . This is above the generally accepted range of  $10^{-4}$  to  $10^{-7}$ . The risk calculated for PAHs from the other two routes is  $2.1 \times 10^{-5}$  (Ohio river water) and  $1.5 \times 10^{-5}$  (soil contact).

Data to quantify other exposure pathways were not available. On-site inhalation of airborne particulates and off-site ingestion of contaminated ground water are suspected as important because of high site concentration and opportunities for dispersion and transformation.

## 1.0 INTRODUCTION

On-site storage for over 25 years of spent cathode material (potliner) and scrubber sludge wastes consisting primarily of cyanide, alkali, sodium, aluminum and fluorides from aluminum processing at the Ormet Corporation plant site in Monroe County, Ohio has resulted in soil and ground-water contamination. Organic contamination (polycyclic aromatic hydrocarbons, PAHs) of the ground water has also been detected. The source of this contamination is not known, but may have its origin in the manufacture on site or use of the carbon anodes in aluminum reduction cells (pots). Extensive well pumping has induced recharge of the aquifer from the Ohio River and also may have resulted in the introduction of river-borne organic chemicals to the aquifer. The release or potential release of inorganic and organic contaminants from this site potentially endangers human health, welfare and the environment. Human health at the Ormet site may be at risk from ingestion of contaminated ground water, inhalation of contaminated dust and direct contact with contaminated soils. Human health in the Hannibal, Ohio and New Martinsville, WV region may be at risk from human ingestion of contaminated water following off-site migration of ground-water and waste-water discharge of Ormet contaminants into the Ohio River.

### 1.1 Site Description and History

#### 1.1.1 Geographic Location

The Ormet Corporation plant site is located in Ohio on the west bank of the Ohio River, approximately two and one-half miles northeast of Hannibal, Ohio and two and one-half miles north of New Martinsville, West Virginia (Figure 1-1). The site is situated along the inside of a meander and occupies the northeastern half of a gently inclined flood plain deposit (Buck Hill Bottom), which is flanked by older river terraces.

#### 1.1.2 Facility Description

The plant is used to reduce alumina to aluminum metal and has been in operation for at least 25 years. Located on the site are several buildings, above ground tanks, roads, railroad tracks, a construction material scrap dump pile, five holding ponds (termed "disposal ponds"), two areas formerly containing above ground piles for storage of potliner processing wastes (termed "waste pot storage"), and three carbon sludge piles (not shown, but apparently located to the west of the construction material scrap dump pile) (Figure 1-2). Leaching of surface water and waste water through the holding lagoons and potliner piles has resulted in ground-water contamination. Up to 6 million gallons of water per day are used for processing and sanitary purposes at the Ormet and neighboring Consolidated Aluminum Company (CAC) facilities (Geraghty and Miller 1984). There are about 1,700-2,000 workers at the Ormet plant and an additional 500-1,000 workers at the CAC facility. Potable water for these workers comes from the CAC well located west of the disposal area on the adjacent CAC property (location not shown on Figure 1-2). No contamination has been reported at this well.

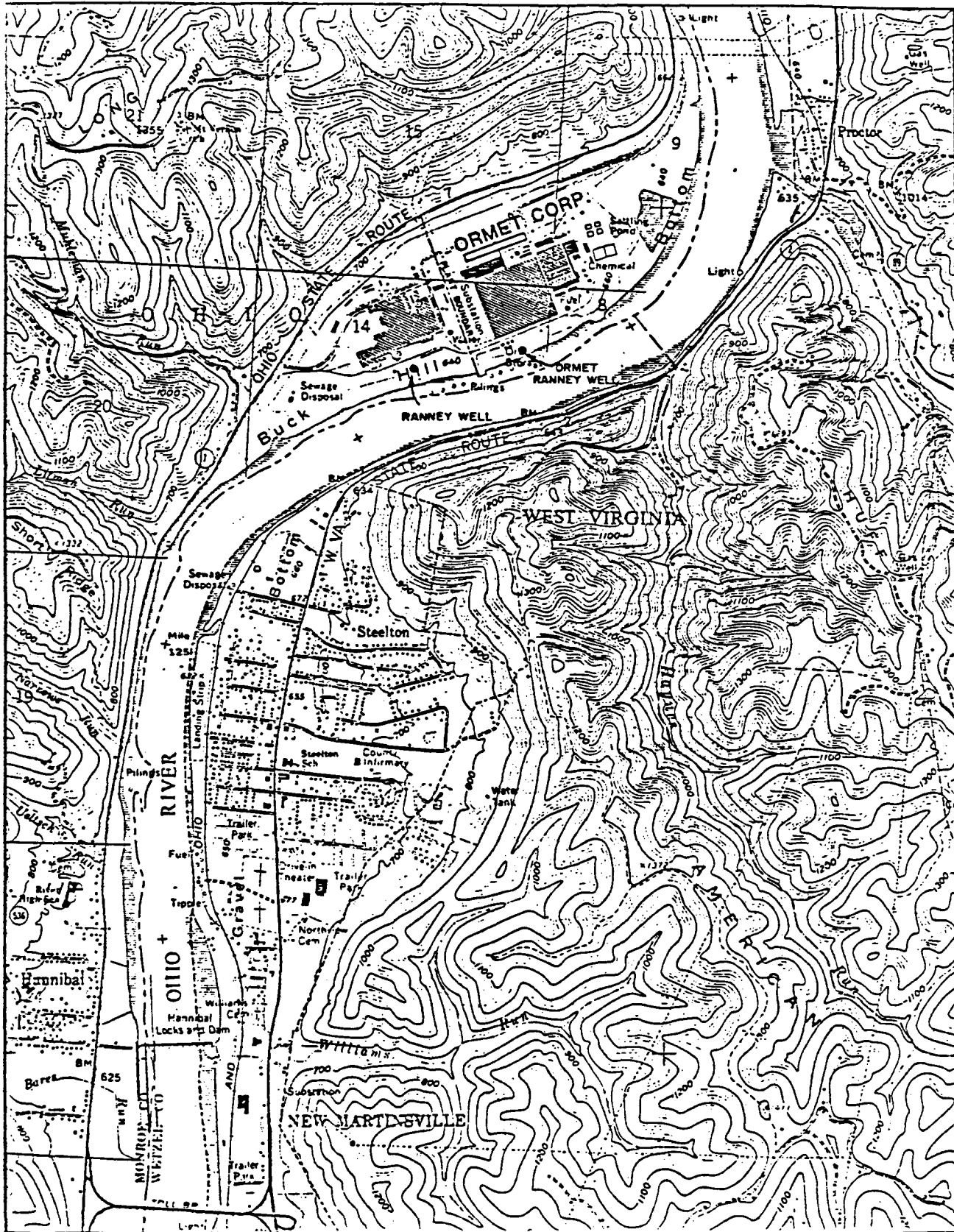


FIGURE 1-1 LOCATION OF THE ORMET CORPORATION PLANT SITE

BASE MAP SOURCE: USGS NEW MARTINSVILLE QUADRANGLE



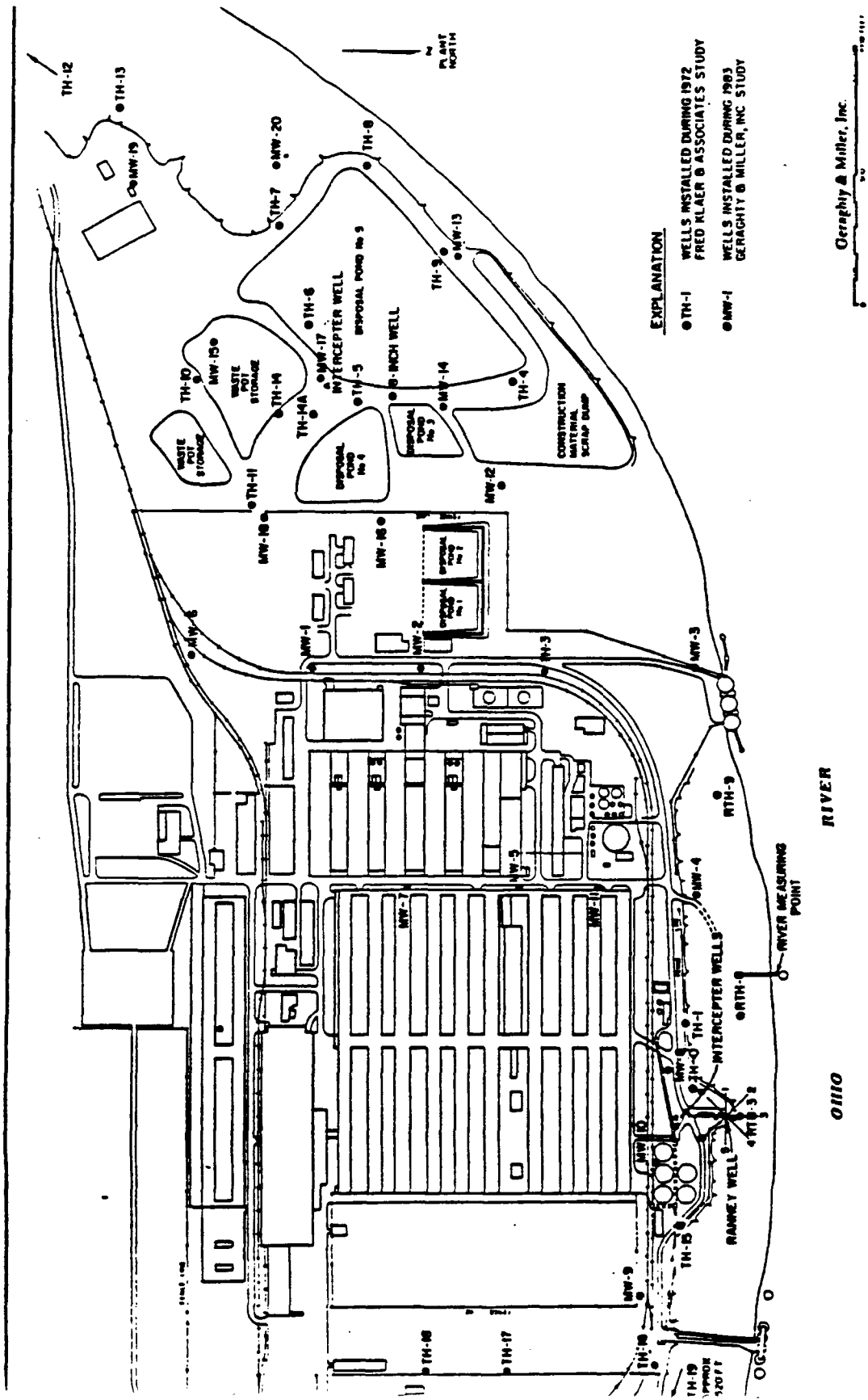


FIGURE 1-2 DETAIL OF ORMET CORPORATION PLANT SITE AND MONITORING WELL LOCATIONS

### 1.1.3 Management Practices/Site Use/Site Modifications

Starting in 1958, when the Ormet plant began operating, spent cathode material (potliner; i.e., carbon-based material with alkaline impurities containing fluoride, cyanide, sodium and ammonia) accumulated in several areas to the northeast of the plant site (Figure 1-2). Surface impoundments (disposal ponds No. 1 through 5) were used for the disposal of wet scrubber sludges (calcium-based salts and cryolite,  $\text{Na}_3\text{AlF}_6$ ). As sludge material accumulated in the disposal ponds the inlet location was moved.

In August 1968, Ormet began operating a cryolite recovery plant, and disposal pond No. 5 began to receive very alkaline sludge containing sodium-based salts including  $\text{NaF}$ ,  $\text{Na}_2\text{SO}_4$ ,  $\text{Na}_2\text{CO}_3$ ,  $\text{Na}_3\text{AlF}_6$  and  $\text{NaAlO}_2$  as well as  $\text{Ca}(\text{OH})_2$  and  $\text{CaCO}_3$ . This material was placed on top of the older calcium-based compounds.

By July, 1971, the process water well (Ranney well) began to produce alkaline, discolored water. Consequently, two interceptor wells (Nos. 1 and 2) were installed in 1972 about 200 feet north of the Ranney well to intercept the contaminant plume before it reached the Ranney well. Contaminated ground water from interceptor wells Nos. 1 and 2 and interceptor well No. 3 (installed in 1982 adjacent to the southwest corner of the No. 5 disposal pond in order to intercept contaminated ground water before it reached the Ormet Ranney well) is a major waste-water source at the Ormet site. Prior to 1983 this waste water was routed first through a lagoon and then to Outfall 004 which discharges into the Ohio River. In 1983, Ormet bypassed the lagoon to lessen the leaching of contaminants into ground water.

In 1976, Ormet began to neutralize sludge from the cryolite recovery plant prior to discharge into the No. 5 disposal pond.

In 1981, the cryolite recovery portion of the plant was shut down and sludge disposal practices were discontinued. Dry flume scrubbers were installed to replace the wet scrubbers. A plant clean up effort was also initiated; spent cathode and other debris accumulated in the potliner storage areas were hauled away.

### 1.2 Potential Sources of Contamination

The potential source of contamination at the site is an approximately 50-acre area east and northeast of the plant buildings. Disposal ponds that received wet scrubber sludges and plant process water (until 1981 and 1983 respectively), potliner waste disposal areas and carbon sludge mounds are found in this area. Geraghty and Miller (1984) surmised that leachate from the potliner storage areas caused the most severe contamination of the underlying aquifer, while the river-recharged aquifer under the disposal ponds was less contaminated. However, there is only weak evidence on which to base this conclusion, and until more data on more contaminants are collected, the entire area must be viewed as a potential source of contamination.

Another source of contamination is the outfall of plant process water and interceptor well water through Outfalls 001-004 to the Ohio River. Outfall 004 appears to receive most of the interceptor well water. The interceptors

pump contaminated ground water from beneath the site to protect the on-site well that is used for process water in the plant. (They cause less contaminated Ohio River water to migrate to the Ranney well). The relative contributions of the plant waste water and ground water contaminated by leachate from the disposal areas to this source of contamination are not known.

### 1.3 Contaminants Found at the Ormet Site

Ormet sponsored hydrogeological investigations of the aquifer at the plant site in 1972, 1977, 1978 and 1984. These are summarized by Geraghty and Miller (1984). The studies examined primarily inorganic contaminants leached from the disposal area that made the ground water undesirable for process water uses. Twenty monitoring wells were drilled on the plant site in 1983 and sampled in 1983 and 1984. It is these wells and summaries of older monitoring efforts sponsored by Ormet that are the source of the data on ground-water contamination by cyanide and fluoride shown in Table 1-1. Too many changes in plant practices and Ohio River levels have occurred over this time period to ascertain any time trend in amounts of inorganic substances released to the aquifer, although the increasing influence of the Ohio river on the aquifer may have reduced average concentrations of fluoride and chloride between 1972 and 1984 (Geraghty and Miller 1984).

No other comprehensive surveys of contamination at the plant have been performed as evidenced by the small number of samples on which all data with the exception fluoride and cyanide are based. The remainder of the data in Table 1-1 on trace metals, phenol and PAHs comes from NPDES Compliance Inspection Reports filed by the Ohio EPA (OEPA) in 1981 and 1983-1986. Some of the data were collected by Ormet and some by OEPA personnel. A priority pollutant analysis was obtained by USEPA in 1984 on Outfall 004 and is the source for the PAH data. (Other available analyses done by a commercial laboratory in 1985 did not detect the water-borne organics found by USEPA and were not used in Outfall 004 results.) The USEPA and Ormet results of priority pollutant analyses of disposal pond solids, one in 1984 and one in 1985, were combined in Table 1-1. No samples are available for soil in the potliner or carbon sludge disposal areas.

The monitor wells and interceptor wells are representative of shallow alluvial aquifer characteristics beneath the disposal area and plant. The monitor wells are not pumped and, therefore, reveal contaminant concentrations over a small area. The interceptor wells are down gradient of the disposal areas and are heavily pumped (about  $5.4 \times 10^6$  liters/day from 1983-1986) and so draw water from a large portion of the aquifer around the plant. Outfall 004 receives contaminated water from the interceptor wells, as well as storm water run-off and plant waste cooling water. Outfall 004 currently empties into the Ohio River along with Outfalls 001, 002 and 003. The Ranney well is used for plant process water that is drawn into the aquifer from the nearby Ohio River, hence the similarity of contaminant concentrations here and in the sample labeled "River Intake" and the generally lower contaminant concentrations than in other ground-water samples. It is not known if the intake is up- or down-river from Outfall 004. Disposal ponds 1-5 were all sampled to generate the values for sediment solids in Table 1-1, but there are no data for any other part of the large disposal area east of the plant. No off-site data are available for comparison.

TABLE 1-1 SUMMARY OF ANALYTICAL RESULTS<sup>(a)</sup>

Contaminant	Ground Water			Process Water <sup>(b)</sup>		Disposal Pond Sediment, <sup>(b)</sup> mg/kg
	Monitor Wells, mg/L	Interceptor Wells, <sup>(c)</sup> mg/L	Outfall 004, <sup>(d)</sup> mg/L	Ranney Well, mg/L	River Intake, mg/L	
Chromium						
range	ND-0.13 <sup>(e)</sup>	ND-0.014	0.03-0.05	ND	ND-0.02	0.014-98
mean, (std dev)	0.05, (0.05)	0.01, (0.01)	0.04, (0.01)	-	0.01, (0.01)	42.7, (38.4)
n <sub>1</sub> /n <sub>2</sub>	4/5	2/3	4/4	0/2	1/2	6/6
Copper						
range	0.02-1.28 <sup>(e)</sup>	0.03-0.059	0.025-0.05	ND	ND-0.08	0.02-110
mean, (std dev)	0.40, (6.22)	0.05, (0.01)	0.04, (0.01)	--	0.04, (0.06)	51.8, (42.1)
n <sub>1</sub> /n <sub>2</sub>	5/5	3/3	4/4	0/2	1/2	6/6
Cyanide						
range	ND-195 <sup>(g)</sup>	1.15-3,450	2-920	0.008-0.01	0.005-6.4	10-228
mean, (std dev)	11.61, (32.85)	691.1, (1,313.4)	185.4, (410.6)	0.009, (0.001)	1.61, (3.20)	108.8, (111.3)
n <sub>1</sub> /n <sub>2</sub>	83/88	7/7	5/5	2/2	2/2	6/6
Fluorides						
range	ND-1,260 <sup>(g)</sup>	23-54.5	25-47	0.9-1.3	0.9-43	10-22
mean, (std dev)	101, (212.3)	38.25, (13.07)	36.5, (8.67)	1.10, (0.28)	21.95, (29.77)	15.4, (4.45)
n <sub>1</sub> /n <sub>2</sub>	149/153	4/4	5/5	2/2	2/2	5/5
Phenol						
range	ND <sup>(e)</sup>	ND-0.003	ND-0.03	ND	ND	ND-1.0
mean, (std dev)	-	0.001, (6.001)	0.026, (0.39)	-	-	0.17, (0.41)
n <sub>1</sub> /n <sub>2</sub>	0/5	2/5	3/4	0/2	0/2	1/6
PAHs <sup>(h,i)</sup>						
Benzo(a)anthracene						
range	ND	ND	0.021 <sup>(i)</sup>	-	ND	0.006-0.065
mean, (std dev)	-	-	-	-	-	0.021, (0.02)
n <sub>1</sub> /n <sub>2</sub>	0/5	0/1	1/1	-	0/1	6/6
Benzo(b+k)fluoranthene						
range	ND	ND	0.043	-	ND	ND-0.110
mean, (std dev)	-	-	-	-	-	0.029-0.037
n <sub>1</sub> /n <sub>2</sub>	0/5	0/1	1/1	-	0/1	5/6
Benzo(a)pyrene						
range	ND	ND	0.0095	-	ND	0.004-0.160
mean, (std dev)	-	-	-	-	-	0.042, (0.05)
n <sub>1</sub> /n <sub>2</sub>	0/5	0/1	1/1	-	0/1	6/6
Chrysene						
range	ND	ND	0.043	-	ND	0.006-0.110
mean, (std dev)	-	-	-	-	-	0.029, (0.03)
n <sub>1</sub> /n <sub>2</sub>	0/5	0/1	1/1	-	0/1	6/6
Pyrene						
range	ND	ND	0.05	-	ND	ND-0.038
mean, (std dev)	-	-	-	-	-	0.016, (0.01)
n <sub>1</sub> /n <sub>2</sub>	0/5	0/1	1/1	-	0/1	5/6
Total PAHs <sup>2</sup>						
range	ND	ND	0.166	-	ND	0.035-0.253
mean, (std dev)	-	-	-	-	-	0.120, (0.078)
n <sub>1</sub> /n <sub>2</sub>	0/5	0/1	1/1	-	0/1	6/6

a) This data has not been subjected to USEPA quality assurance review.

b) All data from 1985 (OEPA).

c) PAH data from 1985. All others from 1983-1985 (OEPA).

d) Non-PAH data from 1981, 1983-1986 (OEPA).

e) Samples collected in 1985 (OEPA).

f) n<sub>1</sub> = number of samples in which contaminant was detected; n<sub>2</sub> = number of samples analyzed.

g) Samples from 1983, 1984, 1985. Geraghty and Miller(1984), OEPA.

h) OEPA( 1985); Martel Laboratories analyses never detected PAHs in water samples. Only in sediment solids in disposal ponds.

i) Outfall water PAH conducted by EPA laboratories (OEPA 1984). Martel Laboratories 1985 data. (OEPA 1985) not used since water samples did not detect PAH.

Source of Data: Geraghty and Miller (1984), OEPA (1981, 1983-1986)

Detectable amounts of all analyzed contaminants were found in disposal pond soils. Ground-water and Outfall 004 samples indicated elevated concentrations (relative to the Ranney well) of all contaminants except phenol. Cyanide exhibited especially high ground-water contamination. PAHs were detected by the USEPA in the outfall and in soil from the disposal areas that may be their source. Water samples from the same outfall and five monitoring wells analyzed by a commercial laboratory found no detectable amounts of PAHs. Most data available was for cyanide. Figure 1-3 (Geraghty and Miller 1984), showing cyanide concentrations in ground water at the plant site illustrates a source under the disposal area, dilution by river water infiltration toward the river and contaminant flow and dilution down gradient to the southwest.

#### 1.4 Selection of Indicator Chemicals

Indicator chemicals were selected from contaminants of concern using available data (Geraghty and Miller 1984, OEPA 1981, 1983-86) and in accordance with the guidelines in the Endangerment Assessment Handbook (USEPA 1985) and Superfund Public Health Evaluation Manual (USEPA 1986c). The indicator chemicals selected are:

- Chromium
- Copper
- Cyanide
- Fluoride
- Phenol

Polycyclic aromatic hydrocarbons:

- Benzo(a)anthracene
- Benzo(b+k)fluoranthene
- Benzo(a)pyrene
- Chrysene
- Pyrene

Toxicity and amount detected were the most important criteria for selection. Chromium and copper were selected because they are toxic trace metals and occur in both disposal soils and ground water significantly above detection limits. Aluminum and manganese were also found at high levels, but were not toxic enough to cause concern. Nickel and zinc were only sporadically present.

Cyanides and fluorides are found at high levels in all areas sampled (ground water, soil, outfall) and are among the 17 chemical constituents regulated in the Ohio River by the State of Ohio. Phenol is similarly regulated and high levels of phenol were detected at Outfalls 003 and 004 in 1981 (OEPA 1981).

The PAHs were selected because they are potential carcinogens with high toxicity constants (USEPA 1986b) and because they were either detected in both Outfall 004 and disposal pond soil at levels twice background or blanks or because of very high concentrations in any medium. Other PAHs were detected that did not fit this criterion.

Bis(2-ethylhexyl)phthalate was found at the same concentrations as the PAHs in soils and water, but its toxicity constant is two orders of magnitude less than the PAHs, and so it was not selected.

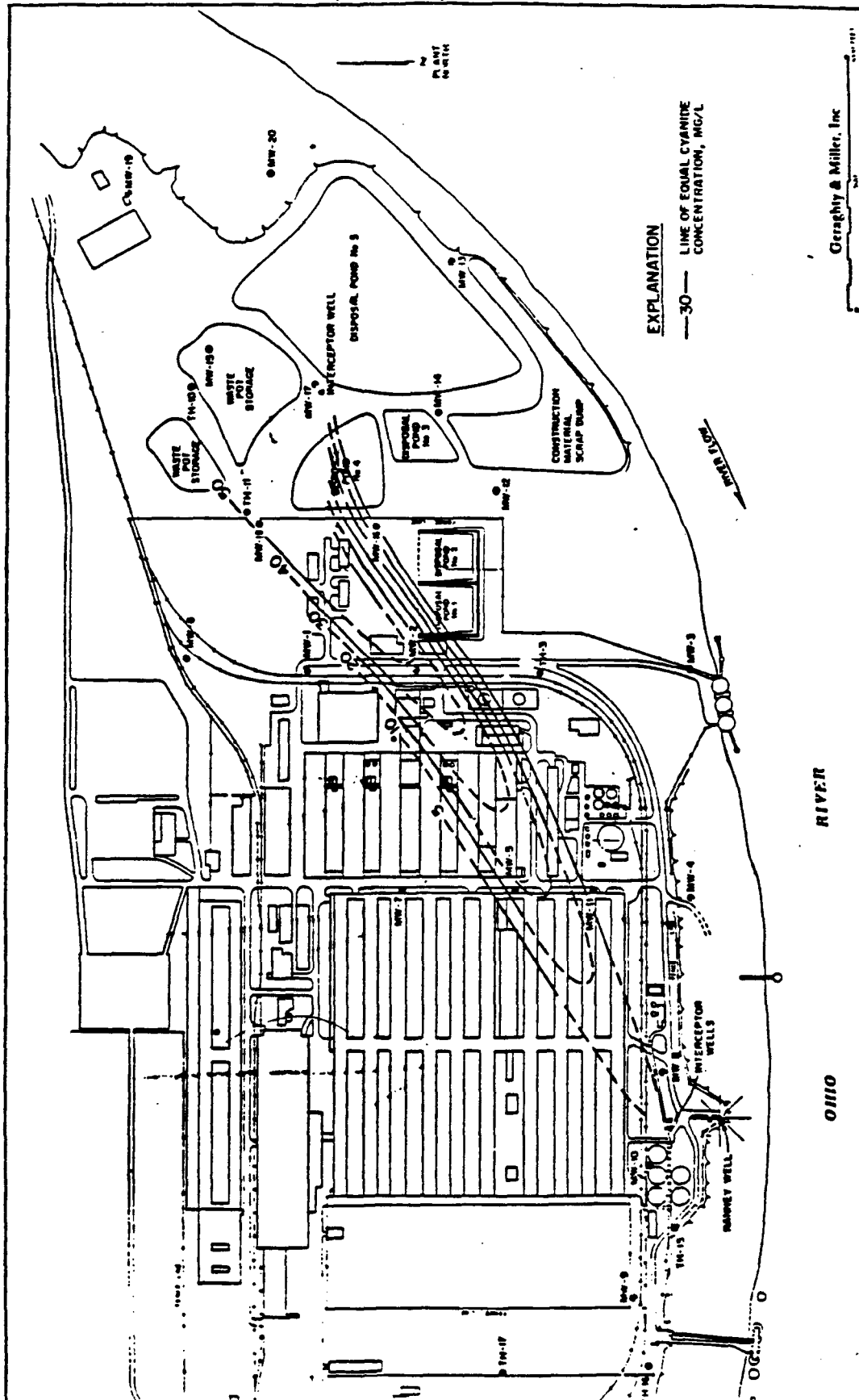


FIGURE 1-3 CYANIDE ISOPLETH MAP AT THE ORMET CORPORATION PLANT SITE

## 2.0 ENVIRONMENTAL FATE AND TRANSPORT ANALYSES

### 2.1 Factors Affecting Migration

#### 2.1.1 Physical-Chemical Properties of Indicator Chemicals

Physical and chemical properties of the ten indicator chemicals are listed in Table 2-1. Water solubility is the maximum concentration of a chemical that dissolves in water at a specific temperature and pH (here, 20 C and neutral pH). The pH in Ormet plant ground waters can exceed 10 so true solubility may differ significantly from the table value. More soluble contaminants may migrate more readily in ground water and surface run-off from the disposal areas.

Chemicals with a specific gravity greater than one will tend to sink in a freshwater aquifer, while chemicals whose specific gravity is less than one will tend to float. Density differences of about 1% are known to influence fluid movement in the subsurface (Mackay et al. 1985).

Vapor pressure is a relative measure of the volatility of a chemical in its pure state. Higher vapor pressures indicate higher volatility. Henry's Law constant is also a measure of the tendency of a chemical to migrate in air; it is the product of molecular weight and vapor pressure divided by water solubility.

The organic carbon partition coefficient ( $K_{oc}$ ) is a relative measure of a chemical's tendency to sorb to soils and sediments. Low values indicate that a substance is more leachable and mobile. High values indicate strong sorption and perhaps longer persistence in soil phases.  $K_{oc}$  is soil independent and site-specific soil properties can greatly alter sorption. High  $K_{oc}$  values of substances in water also indicate a greater likelihood of bioconcentration by organisms. The log octanol-water partition coefficient ( $K_{ow}$ ) is a measure of how a chemical is distributed at equilibrium between octanol and water. Log retardation factors of many organic chemicals have been linearly related to their  $K_{ow}$  by Paterson et al. (1985). High  $K_{ow}$  would indicate slow movement of the chemical relative to ground-water flow.

#### 2.1.2 Fate and Transport Processes Affecting Indicator Chemicals

The information presented below is derived from Callahan et al. (1979) and USEPA (1985a).

##### Chromium

Anionic forms of chromium are very soluble and therefore mobile in the aquatic environment. Hexavalent chromium (Cr VI) may sorb to organic materials in natural waters; it is a strong oxidizing agent and reacts with reduced materials to form trivalent chromium (Cr III). Most Cr III is hydrolyzed and precipitates as chromium hydroxide. Conditions that favor the formation of Cr III also favor its precipitation and adsorption in sediments. In air, chromium is mostly associated with particulates. It is adsorbed strongly onto clay and organic particulate matter.

TABLE 2-1 SELECTED PHYSICAL PROPERTIES OF INDICATOR CHEMICALS<sup>(a)</sup>

Chemical	Molecular Weight, g/mole	Solubility in Water, mg/L	Vapor Pressure, mm Hg	Specific Gravity, 20 C	Henry's Law Constant, atm-m <sup>3</sup> /mol	Log Octanol/Water Partition Coefficient, log K <sub>ow</sub>	Carbon Partition Coefficient K <sub>oc</sub> , mL/g
Chromium	52	-	0	7.2	-	-	-
Copper	64	-	0	8.9	-	-	-
Cyanide <sup>(a)</sup>	27	10 <sup>6</sup>	657.8	0.69	-	-0.25	-
Fluorides <sup>(b)</sup>	-	-	-	-	-	-	-
Phenol	94	9.3 x 10 <sup>4</sup>	0.34	1.07	4.54 x 10 <sup>-7</sup>	1.42	14.2
PAHs							
Benzo(a)anthracene	228	0.0057	2.2 x 10 <sup>-8</sup>	-	1.16 x 10 <sup>-6</sup>	5.60	1.38 x 10 <sup>6</sup>
Benzo(b+k)fluoranthene	252	0.0014	5.0 x 10 <sup>-7</sup>	-	1.19 x 10 <sup>-5</sup>	6.06	5.5 x 10 <sup>5</sup>
Benzo(a)pyrene	252	0.0012	5.6 x 10 <sup>-9</sup>	-	1.55 x 10 <sup>-6</sup>	-	5.5 x 10 <sup>6</sup>
Chrysene	228	0.0018	6.3 x 10 <sup>-9</sup>	1.274	1.05 x 10 <sup>-6</sup>	5.61	2.0 x 10 <sup>5</sup>
Pyrene	202	0.132	2.5 x 10 <sup>-6</sup>	1.271	5.04 x 10 <sup>-6</sup>	4.88	3.8 x 10 <sup>4</sup>

(a) Various compounds; values listed are for hydrogen cyanide.

(b) Various compounds.

Source: USEPA (1986c)



### Copper

Copper has an affinity for hydrous iron and manganese oxides, clays, carbonates and organic matter. Sorption to these materials increases the solid phase and decreases the dissolved phases of copper. In the presence of soluble organic matter, complexation of copper with organic ligands can occur, which favors the prolonged dispersion of copper in solution. The amounts of copper in solution are strongly pH dependent. Generally, ionic copper is more soluble in low pH waters and less soluble in high pH waters. Copper is strongly bioaccumulated by plants and animals. Atmospheric transport of copper compounds can also occur.

### Cyanide

The transport and fate of cyanides will depend on their form. Under most natural conditions hydrogen cyanide (HCN) will be the predominant cyanide. It is completely soluble in water, will volatilize rapidly from water and soil and will diffuse rapidly once volatilized. Iron, gold, cadmium, nickel, silver and zinc form metalocyanides. Cadmium and zinc complexes dissociate in water, and the stability of copper and nickel cyanides depends on pH. Iron and cobalt cyanide complexes are very stable. Data in Geraghty and Miller (1984) indicate that much of the cyanide in the ground water at the Ormet site is complexed as  $\text{Fe}(\text{CN})_6^{4-}$ . Cyanide mobility in soils is pH dependent. Generally cyanide is very mobile in soils, with lower mobility and higher sorption at low pH and high iron oxide and clay concentrations. The ultimate fate of cyanides in water and soils is volatilization or biodegradation.

### Fluorides

Fluorine is the most electronegative of all elements and exists naturally in the form of fluoride. Many cations combine with fluorine to form fluorides. The most abundant fluoride is calcium fluoride ( $\text{CaF}_2$ ), which is relatively insoluble in water. Aluminum fluoride and sodium fluoride are more soluble and can be transported as leachate in ground water. Solubility and transport are temperature and pH dependent. The ultimate fate of these inorganic compounds is probably precipitation or biotransformation.

### Phenol

Phenol is highly soluble in water. The low  $K_{ow}$  of phenol indicates that it would not be significantly retarded in ground-water flow. Its low  $K_{oc}$  suggests that sorption and bioaccumulation are not important fate processes. Biodegradation can be a significant fate process in aquatic systems and soils where microorganisms are abundant. Photooxidation and metal-catalyzed oxidation are important degradative processes. There is a possibility that phenol in surface waters can volatilize, but rapid oxidation in the troposphere makes any significant atmospheric transport unlikely.

### Polycyclic Aromatic Hydrocarbons

The PAHs are a class of compounds consisting of substituted and unsubstituted polycyclic aromatic rings formed by the incomplete combustion of organic

materials. Their properties vary with their size and shape. In general, the low molecular weight PAHs are more mobile in ground water, soil and air. The PAHs as a class have  $K_{OC}$  values ranging from 14,000 to 5,500,000. This indicates that they should be strongly adsorbed onto soils high in organic matter. Therefore, transport on particles in water and air is the likely dominant transport process. The lower molecular weight (range 116 to 278) PAHs have the highest vapor pressures and could volatilize and be transported in air, but this is not usually a significant process.

PAHs are relatively insoluble in water, but the dissolved fraction may undergo direct photolysis. The PAHs are bioaccumulated, but also quickly metabolized and eliminated from most organisms (shellfish are an exception). Biodegradation and biotransformation are probably the ultimate fate processes for PAHs. Biodegradation may occur more readily in soils than aquatic systems.

### 2.1.3 Site-Specific Factors Affecting Migration

#### 2.1.3.1 Topography

The Ormet site occupies a bottomland in a meander bend of the Ohio River. Flanking the Ohio River are two main river terrace levels with lower and upper terrace elevations averaging about 630 and 665 feet above mean sea level (msl), respectively. The upper terrace, which is occupied by the main plant facilities, is bounded on the northwest by a steep valley wall that rises to an elevation of 1,300 feet within a mile. The lower terrace comprises a relatively narrow strip of land bounded by the Ohio River. The Ohio River pool elevation in this area ranges from 620 to 624 feet above mean sea level and, as a result of the Hannibal lock and dam, tends to remain fairly constant throughout high- and low-flow periods (Geraghty and Miller 1984). The filled sludge disposal ponds are elevated about 25 feet above the original topographic surface in a terraced configuration.

#### 2.1.3.2 Geology

The region of interest is underlain by Paleozoic sedimentary rocks. Bedrock at the site is the Dunkard Formation, a Permian unit consisting of shale, sandstone and coal. The top of bedrock decreases from about 610 feet msl (above mean sea level) along the western margin of the site to about 560 feet msl at the bank of the Ohio River. Depth to bedrock ranges from 50 to 100 feet and averages about 75 feet. Unconformably overlying the bedrock are bottomland alluvial deposits that exhibit floodplain and river terrace features. Upper river terraces consist of sand and gravel and are Pleistocene glacial outwash plains that have been carved into a stepped profile by the downcutting Ohio River. Lower river terraces contain appreciably greater quantities of silt and clay and were formed during more recent elevated river stages.

The Ohio River Valley water table aquifer is a main source for process and drinking water supplies. It is made of sand and gravel alluvial deposits and produces high yields of generally good water quality with total dissolved solids concentrations of 500 ppm or less. Ground water from the Paleozoic bedrock is more mineralized and exhibits lower yields. Consequently it has

not been extensively developed in the immediate area. The Geraghty and Miller (1984) report provides no flow velocity and direction data, chemical analyses or hydrologic properties of this underlying aquifer. There are also discontinuous zones of perched ground water that are often encountered at shallow depths (20 feet or less) beneath the main plant facility and are believed to result in part from storm drain leakage (Geraghty and Miller 1984).

#### 2.1.3.3 Hydrogeology

The Ohio River occupies the topographically lowest position in the valley, is the main body of surface water in the area and receives the ground-water discharge. At the site, about 6 million gallons of water are pumped daily from the alluvial aquifer via the two Ranney wells (Dames and Moore 1977). This extensive pumpage has induced recharge from the river. Consequently, the quality of water derived from these pumping wells is significantly dependent upon river water quality and is thus susceptible to numerous upstream sources of contamination.

Twenty old monitoring wells (TH-0 through TH-19) and twenty new monitoring wells (MW-1 through MW-20) are located throughout the site area and can be used to delineate leachate plumes and ground-water flow directions (Figure 1-2). All monitoring wells were drilled only to the top of bedrock, and consequently cannot be used to evaluate potential contamination and transport in the underlying bedrock aquifer. Prior to development of the aquifer (1956), the water table probably sloped from north to south with ground water flowing toward and discharging into the Ohio River. According to Geraghty and Miller (1984), pumping of the Ranney wells has created two large cones of depression (drawdown = 5 to 10 feet), and caused the water table to drop below the level of the river thereby inducing recharge of the aquifer from the river (Figure 2-1).

In 1973, the Hannibal Lock and Dam was closed resulting in about a 20-foot rise in the river-pool elevation, a 10-foot rise in the water table in the area of the disposal ponds and about a 5-foot rise in the water table in the vicinity of Ormet's Ranney well. Contaminant leaching through the No. 5 disposal pond and pumping of the Ormet Ranney well resulted in deteriorated water quality in the Ranney well in 1971. As an interim solution, two interceptor wells were installed in 1972 north of the Ranney well to intercept the plume of contaminated ground water before it reached this well. Cessation of disposal of sludge into the No. 5 disposal pond in 1981 has resulted in the disappearance of fluid mounding beneath the No. 5 pond and a decrease in the chemical concentration in the ground water.

There are no monitoring wells located upgradient and downgradient from the site that may be used to determine background ground water quality and potential off-site migration of contaminated ground water.

Monitoring wells 19 and 20, although upgradient from the site, are not located sufficiently upgradient to be unaffected by the ground-water pumping of the interceptor wells. The CAC well, located downgradient, can provide some indication of off-site migration. Further down-gradient locations are unavailable.

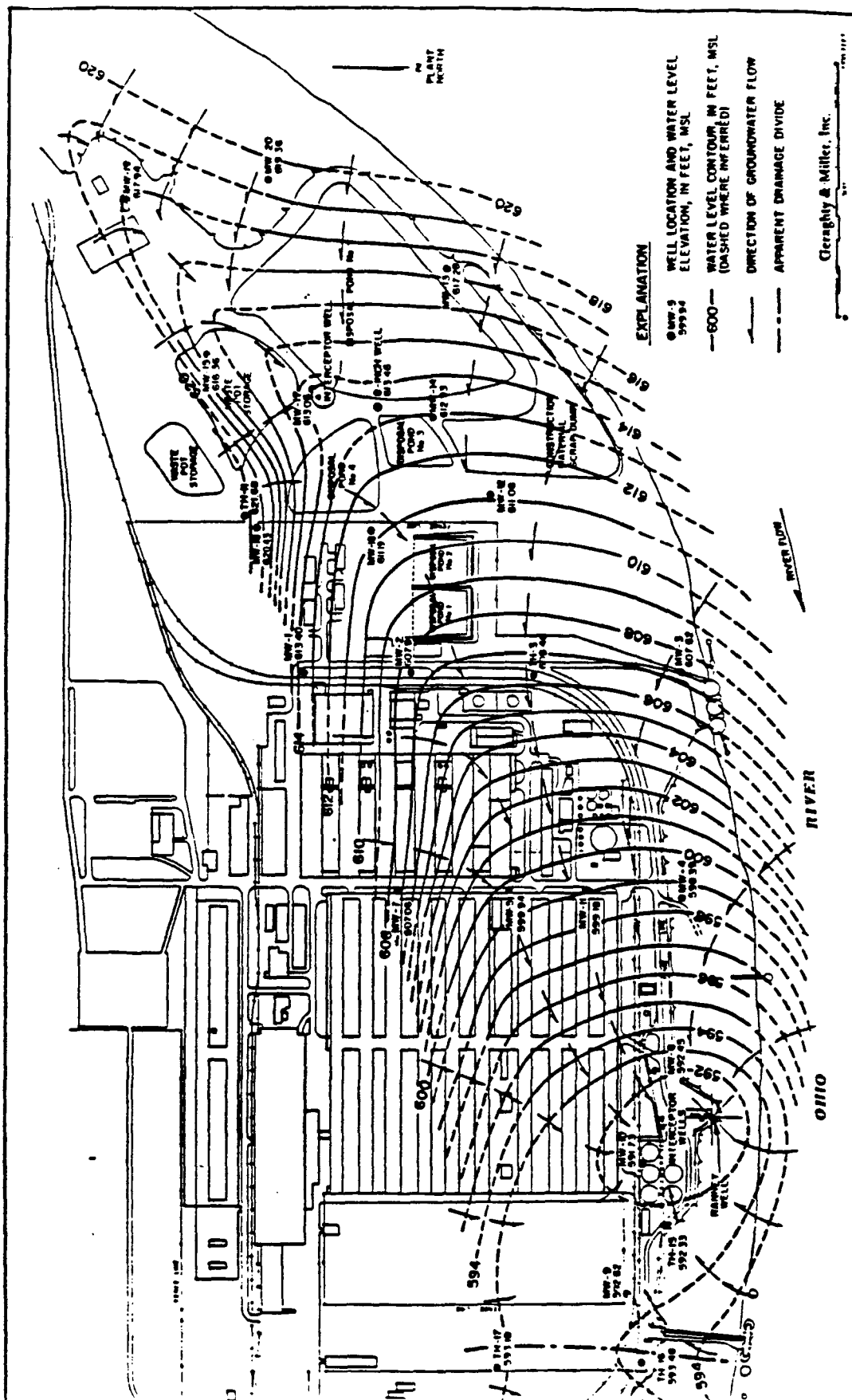


FIGURE 2-1 INFERRER WATER TABLE CONTOUR MAP AT THE ORMET CORPORATION PLANT SITE

#### 2.1.3.4 Hydrology

Aquifer sediments typical of the central plant area have a transmissivity (T) of about 60,000 gpd/ft<sup>2</sup>, a hydraulic conductivity (K) (or, k, coefficient of permeability) of about 1,900 gpd/ft<sup>2</sup> ( $\approx 10^{-1}$  cm/sec) and a storativity (S) (coefficient of storage) of 0.19 (dimensionless) (Fred Klaer and Associates 1972). Using a hydraulic gradient (I) of 0.008 to 0.009 ft/ft and an assumed effective porosity (n) of 0.25 (dimensionless), Geraghty and Miller (1984) estimated from the relationship  $V=(KI)/n$  that ground water beneath the northeastern parts of the plant area is moving at a rate (V) of about 3,300 to 3,700 feet (0.6-0.7 mi) per year. These velocities are about four times faster than those estimated in Fred Klaer and Associates (1972) because of the earlier omission of the effective porosity factor.

#### 2.1.3.5 Climatic Factors

The Ormet plant site experiences a temperate continental climate. In New Martinsville, WV summer temperatures average 73 F (23 C) while winter temperatures average 34 F (1 C), yielding a mean annual temperature of about 53 F (22 C). Total annual precipitation is 44 inches. The site is located in a latitudinal zone of prevailing westerly winds, but Geraghty and Miller (1984) provides no additional data about local wind vectors.

### 2.2 Environmental Fate and Contaminant Movement

Potential contaminant migration pathways at the site include:

- Leaching and seepage of contaminants into ground water from disposal ponds and potliner waste piles, and subsurface migration of contaminated ground water to interceptor, processing or drinking water wells on site and migration off site in alluvial or bedrock aquifers.
- Transport of contaminants via surface run-off into the Ohio River and via outfall discharge of contaminated interceptor well water into the Ohio River.
- Airborne transport of contaminants from dried disposal ponds and potliner waste piles and remedial action of plant clean-up activities.

Each of these pathways is discussed below.

#### 2.2.1 Ground-Water Transport

Storage of potliner wastes in piles on the ground surface and of sludge wastes in lagoons lined only with fill has provided a suitable pathway for the leaching of contaminants into the ground water. There is evidence of significant ground-water contamination and migration on site. Monitoring well data demonstrate that ground water pH values are greater than 10.2, and maximum contaminant concentrations are 1,260 ppm fluoride, 195 ppm cyanide and 2,500 ppm sodium. The contaminant plume can be readily traced from the potliner storage area and sludge lagoons to the interceptor wells

(Figure 1-3). Some ground-water contamination appears to the west of the ground-water interceptor wells 1 and 2. Using data given in Geraghty and Miller (1984) and in OEPA NPDES Compliance Reports (1984, 1985) average concentrations at the farthest downgradient well (for which data are available, MW 9) are  $5.7 \pm 1.3$  (std. dev.) ppm fluoride and  $0.25 \pm 0.12$  ppm cyanide. Ground-water flow from the site is to the southwest sub-parallel to the river.

At the present time, the three interceptor wells are the probable discharge zone of some unmeasured portion of the contaminants flowing from the area. These wells presently withdraw about 1 million gallons of water per day. The hydraulic conductivity ( $1,900 \text{ gpd/ft}^2$ ) times the cross-sectional area of the aquifer near these wells (section CC' of Geraghty and Miller 1984, about  $37,000 \text{ ft}^2$ ) times the hydraulic gradient ( $0.009 \text{ ft/ft}$ ) indicates that 0.6 million gallons of water per day would flow naturally through this part of the site. Thus, the interceptor wells are capable of withdrawing all ground water in this area. Ground water not captured by the wells will eventually discharge into the river at an unknown distance downstream from the Ormet site. The extent and velocity off site of the contaminant plume has not been measured.

#### 2.2.2 Surface-Water and Soil Transport

Surface-water run-off at the Ormet site was not measured in the Geraghty and Miller (1984) report. Since there is 20-50 ft of topographic relief across the site from the northwest to the Ohio River, a potential for considerable surface water run-off exists. The disposal ponds are terraced about 25 feet above the local terrain and past practices have resulted in overflow into the Ohio River. There are no available data for suspended solids and associated contaminant concentrations.

The three interceptor wells are discharging  $1.4 \times 10^6$  gal/day ( $2.2 \text{ ft}^3/\text{sec}$ ) of contaminated ground water directly into the Ohio River through Outfall 004. This is the major pathway for migration of contaminants off site. The concentration of contaminants moving off site by this pathway are given in Table 1-1.

#### 2.2.3 Airborne Transport

Inhalation of contaminated dust is also an important exposure pathway. Dried sediment in the disposal ponds and potliner piles may be transported by winds and may represent the greatest exposure pathway for workers at the Ormet facility. There are no available data on local wind velocities and directions. The prevailing winds in the region may be west-northwest, but wind directions and velocities along low-lying river meanders are likely to be different and highly site-specific. There are likewise no data for concentrations of contaminants in airborne dust and little on the variability of surface soil contaminant concentrations over the 50-acre area.

### 3.0 EXPOSURE EVALUATION

#### 3.1 Routes of Exposure

There is a potential for toxic substances disposed at the site to reach the public through a number of pathways. At the Ormet site, direct contact with soils, inhalation of airborne dust and ingestion of ground water appear to be the most significant routes of exposure. Off site, surface-water transport and possibly ground-water transport to drinking water supplies appear to be the most significant routes of exposure. The exposure potential of ingestion of contaminated fish is unknown. However, there is no pronounced tendency of these compounds to permanently bioaccumulate, so these potential exposure routes may not be of major importance. Adequate quantitative data exist to complete only the on-site ground water, on-site dermal contact with soils and off-site surface-water exposure pathways.

##### 3.1.1 Ground Water

The unconfined aquifer at the Ormet site is contaminated from water leaching through the disposal ponds and potliner waste storage piles. At present, much of the contamination migrating downgradient (southwest) is removed from the aquifer by the interceptor wells, although data from MW 9 suggest that some contamination might escape capture by those wells. The Ranney well and the CAC well, which supplies the Ormet drinking water, are both located downgradient from the disposal area and are potentially in danger of contamination from the migrating plume if the interceptor wells cease functioning or pump at lower volumes for any length of time. As the plume migrates away from the storage piles and disposal ponds, its base will broaden while the peak height (maximum concentration) will decrease under the influence of longitudinal and transverse dispersion and dilution by mixing with Ohio River water recharged by pumping at the Ranney and Ormet-Ranney wells (Figure 2-1). There are insufficient data downgradient and off site to accurately predict the ultimate fate of the contaminants in the ground water with and without pumping of the interceptor and Ranney wells. However, it seems likely that most of the plume would discharge downgradient into the Ohio River without pumping by these wells. The hydraulic relationship of the contaminated alluvial aquifer and the underlying bedrock aquifer is unknown, and the direction and rate of flow and use of water in the bedrock aquifer is unknown. There is a potential for human exposure through possible ingestion and dermal contact of contaminated ground water both on the site and offsite.

##### 3.1.2 Surface-Water and Sediment Transport

At present, surface water is the major off-site migration pathway because of discharge of the interceptor well waters directly into the Ohio River. Exposure will be chronic due to the steady discharge and dilution of the contaminants. Removal of sediment sludge and potliner wastes will ultimately result in a decrease of contaminant concentrations in the interceptor well water. Another potential exposure route involving surface water results from nonpoint source runoff of contaminated surface water and sediment from the site into the Ohio River. The exposure potential will depend on the downstream use of the Ohio River surface waters for drinking water, recreation

and fishing. On-site dermal contact with contaminated sediments and site soils is another exposure route, although the number of workers exposed (even during clean-up efforts), the amount of skin exposed and the duration of contact are unknown.

### 3.1.3 Ambient Air

Ormet plant operations and remedial activity have resulted in the drying of waste piles and disposal pond sediments and the removal of some wastes. Therefore, ambient air is another potential primary route of exposure. All workers at the Ormet and CAC facilities (especially those involved in the remedial clean-up activities) may be expected to inhale elevated contaminant concentrations. Potential routes that are less likely to be significant include inhalation of volatiles from contaminated surface waters, ground waters and sediments because volatile concentrations in those materials are low. Off-site inhalation of airborne contamination is also likely to be an insignificant route of exposure because of dilution of air as it migrates off site.

### 3.2 Populations Exposed

#### 3.2.1 Human Populations

The town of Proctor, WV (population of 150) is located about one-half mile upgradient from the site and on the other side of the Ohio River. There are four houses located directly across the Ohio River from the site, and there are 17 houses adjacent to the site located along the southwest margin of Buck Hill Bottom. The town of Steelton WV (New Martinsville, WV; total population of 7,109) is located about one to one and one-half miles downgradient, but on the other side of the Ohio River, and the town of Hannibal, Ohio (population of 650) is located about two and one-half miles downgradient from the site on the same side of the river as the Ormet site (Rand McNally 1987). The nearest Ohio town using the river as its drinking water source is Ironton, OH, which is over 100 miles down gradient. No information is available on West Virginia populations using the Ohio River for drinking water. It is unknown what portion of this population may be endangered by off-site migration or potential migration of contaminated ground water, dust and surface water.

There are about 2,200-3,000 workers at the Ormet and CAC plant sites some of whom are potentially exposed from hypothetical ingestion of and dermal contact with contaminated ground water and inhalation of contaminated dust. The exposure potential of this population will increase greatly if pumping of the interceptor wells is stopped or if additional remedial clean-up activity generates airborne contamination.

The number of people in other potentially exposed populations is unknown. These include persons exposed to contamination via direct contact with the Ohio River, ingestion of contaminated fish and incidental ingestion of contaminated river water.



### 3.2.2 Environmental Populations

The number of animals potentially endangered by drinking contaminated ground water and surface water is unknown. Numerous animal tracks including those of deer, groundhogs and beavers have been identified at the site. It seems likely that the area around Buck Hill Bottom would support a large population of migratory and native birds. Other potentially exposed populations, such as Ohio River fish, have not been identified.

### 3.3 Potential for Exposure

There are insufficient data to fully quantify human and environmental exposures to contaminants released from the Ormet site. There are sufficient data to construct a provisional ranking of exposure pathways and to estimate exposure point concentrations for the three completed pathways. Based on the considerations in Sections 2.1 and 3.1, potential exposure pathways are ranked in approximate order of importance as follows:

- On-site ingestion of and associated contact with contaminated ground water (including ingestion of water from the CAC well if interceptor wells cease pumping)
- On-site inhalation of particulates from on-site soils
- Direct contact with on-site soils
- Off-site ingestion of and dermal contact with surface water
- Off-site ingestion of ground water
- Off-site inhalation of particulates from on-site soils
- Inhalation of volatiles from ground water
- Inhalation of volatiles from surface water
- Inhalation of volatiles from soils
- Ingestion of contaminated fish

On-site ingestion of contaminated ground water is the highest ranked exposure pathway because contaminants have been detected there in high concentrations and are not diluted before ingestion. This exposure pathway remains only a potential pathway as long as the interceptor and Ranney wells continue to pump. The large amount of pumping limits the spread of the plume.

Soils at the site are contaminated over a large area and the disposal lagoons are dry. The site contaminants tend to sorb to particles so that inhalation and direct contact with them on site may be an important pathway. The data on wind speed, direction and soil properties at the site needed to quantitatively estimate erosion and airborne transport of contaminants at the site are unavailable.

Pumped ground water and process water and downgradient ground-water discharge are diluted by Ohio River water, but the discharge is large enough so that this exposure pathway could be significant. Off-site ground water undergoes an indeterminate amount of dilution and degradation but the potential users of the downgradient alluvial aquifer and any hydraulic connection with the bedrock aquifer are unknown.

Off-site inhalation receives a lower ranking because of the likely high dilution and precipitation of airborne contaminants. Most of the contaminants tend to sorb to particles or are not very volatile, and few bioaccumulate for long periods of time, which account for the low rank of the remaining pathways.

There are sufficient data to complete three pathways and estimate exposure point concentrations. These pathways are discussed below. Estimated exposure point concentrations are listed in Table 3-1.

### 3.3.1 On-Site Ground Water

On-site exposure point concentrations in ground water are estimated from monitoring well and interceptor well data collected from 1981-1986. There was no obvious time trend in the data. The monitoring wells detect concentrations over a small volume of the aquifer, while the interceptor wells are downgradient of the disposal area and are heavily pumped. Thus, the interceptor wells represent contaminant concentrations averaged over a larger volume of the aquifer. The highest recorded concentration in the monitor and interceptor wells was used as the upper-bound estimate of contaminant concentration. The mean of interceptor well data was used as the best estimate of on-site concentrations. Only Outfall 004 was measured for PAHs, and since Outfall 004 receives the water pumped by the interceptor wells, these values were used for best estimates of ground-water PAH concentration.

Workers on the site now get their drinking water from the CAC well, and there is no evidence that this well is presently contaminated. Thus, these exposure point concentrations assume a hypothetical cessation of pumping at the interceptor wells and migration of contaminants to the CAC well. They also assume unchanging concentrations. There are no data on persistence or release of contaminants from the disposal soils or on degradation of contaminants in the aquifer.

Off-site concentrations in relevant media cannot be estimated without off-site monitoring data and an acceptable model of site-specific contaminant transport and fate.

### 3.3.2 Direct Contact with On-Site Soils

The only available data on soil concentrations are six samples collected from the dried disposal ponds in 1984 and 1985. The maximum and mean concentrations of contaminants of concern were used for the upper-bound and best estimates, respectively. It is unclear whether or not these were surface soil samples. Variability of concentration across the entire disposal area is unknown.

### 3.3.3 Ohio River Surface Water

Contaminated ground water is pumped from the on-site interceptor wells and is returned to the Ohio River via Outfall 004. This outfall also receives storm-water run-off and plant noncontact cooling waste water. Outfalls 001, 002, and 003 also discharge into the Ohio River, but contaminant concentrations in these outfalls are much lower (by a factor of ten or more) than in

TABLE 3-1 POTENTIAL EXPOSURE POINT CONCENTRATIONS FOR COMPLETE PATHWAYS

Contaminant	On-Site Ground Water, (a) mg/L		Ohio River Surface Water, (b) mg/L		Disposal Pond Soil, (d) mg/kg	
	Upper Bound	Best Estimate	Upper Bound	Best Estimate	Upper Bound	Best Estimate
Chromium	0.13	0.05	$1.9 \times 10^{-5}$	$1.52 \times 10^{-5}$	98	42.7
Copper	1.28	0.40	$1.9 \times 10^{-5}$	$1.52 \times 10^{-5}$	110	51.8
Cyanide	3,450	11.61	0.34	0.07	228	108.8
Fluorides	1,260	101	0.02	0.013	22	15.4
Phenol	0.003	0.001	$1.14 \times 10^{-5}$	$9.8 \times 10^{-6}$	1.0	0.17
PAHs (c)						
Benzo(a)anthracene		0.021		$7.9 \times 10^{-6}$	0.025	0.021
Benzo(b+k)fluoranthene		0.043		$1.6 \times 10^{-5}$	0.110	0.029
Benzo(a)pyrene		0.0095		$3.6 \times 10^{-6}$	0.160	0.042
Chrysene		0.043		$1.6 \times 10^{-5}$	0.110	0.029
Pyrene		0.050		$1.9 \times 10^{-5}$	0.038	0.016
Total PAHs		0.166		$6.3 \times 10^{-5}$	0.253	0.120

- (a) The maximum (upperbound) of ground-water monitor and interceptor wells and mean (best estimate) of more numerous monitoring wells (Table 1-1). Contaminated ground water does not currently reach the CAC drinking water supply well, but could if interceptor wells are shut down.
- (b) Outfall 004 values (Table 1-1) multiplied by 004 discharge (2.2 CFS), divided by the sum of Ohio River minimum weekly low flow expected in a decade and 004 discharge (5802.2 CFS).
- (c) There is only one EPA sample for PAH in water at outfall 004. Since outfall water consists primarily of ground water from interceptor wells (-1 MGD), it is used for ground-water values.
- (d) Disposal ponds and potliner storage areas are currently dry, so direct contact with contaminated soil is possible.

Outfall 004. Therefore Outfall 004 concentrations were used as the point source of contaminants from the site to the Ohio River. Overland run-off from the disposal area and downgradient ground-water discharge from the alluvial aquifer also contribute contaminants to the river, but there are no data available on these pathways.

The following equation (Schultz et al. 1986) provides a rough estimate of the concentration of a substance downstream from a point source release into a flowing water body after dilution of the substance by the receiving water body:

$$C = (C_e Q_e) / Q_t \quad (1)$$

where:

C = concentration of substance in river  
 $C_e$  = concentration of substance in effluent  
 $Q_e$  = effluent flow rate  
 $Q_t$  = combined effluent and stream flow rate

The flow rate of effluent from Outfall 004 is 5.4 million liters per day, or 2.2 CFS ( $\text{ft}^3/\text{sec}$ ). The minimum seven-day, ten-year low flow based on calculations by the U.S. Corps of Engineers that is used by state regulators (Ohio Admin. Code 3745-1-32) is 5800 CFS from river mile 32.4 to river mile 161.8. The Ormet plant is at river mile 123. For example, the mean concentration of cyanide in Outfall 004 is 185.4 mg/L, so the river concentration is :

$$C = (185.4 \text{ mg/L} \times 2.2 \text{ CFS}) / 5,802.2 \text{ CFS} = 0.07 \text{ mg/L}$$

The equation assumes complete mixing of the contaminants. This assumption is not valid within a mixing zone downstream from the point of introduction. This mixing zone can extend for a considerable distance downstream, and concentrations in the mixing zone can be much higher than estimated by the above equation.

The length of the mixing zone is estimated by the following equation (modified from Schultz et al. 1986):

$$MZ = (0.4 wV) / (0.6d^2 (\text{gds})^{1/2}) \quad (2)$$

where:

MZ = mixing zone length  
w = width of water body (900 ft)  
V = volume flow rate of river  
d = stream depth (25 ft)  
s = slope of the stream channel (0.000148 ft/ft)  
g = acceleration due to gravity (32 ft/sec<sup>2</sup>)

Width of the river and slope were taken from USGS topographic maps. From this equation, MZ = 3.06 miles. Thus, these river concentration estimates may be too low for nearby downstream towns of Hannibal and New Martinsville. Furthermore this equation provides in-stream concentrations resulting only from site releases. If total concentrations are desired (they are not used in Table 3-1) upstream contaminant concentrations are added to those estimated by the equation. Finally, the above dilution equation assumes that the contaminants are conservative; for nonconservative (reacting or degrading) substances, it provides only a worst case estimate.

#### 4.0 TOXICOLOGICAL EVALUATION

A number of compounds that have the potential for causing adverse human health and environmental effects have been detected in the soil and ground water at the Ormet Corporation Plant site. On the basis of their occurrence at the site and their toxicological effects, ten chemicals have been selected as being of particular concern: chromium, copper, cyanide, fluoride, phenol and five polycyclic aromatic hydrocarbons (benzo(a)anthracene, benzo(b+k)fluoranthene, benzo(a)pyrene, chrysene and pyrene). Sections 4.1 to 4.6 summarize the adverse effects for each of these contaminants.

The following "applicable or relevant and appropriate requirements" (ARARs) have been identified for the site.

- Drinking Water Maximum Contaminant Levels (MCLs)
- Drinking Water Maximum Contaminant Level Goals (MCLGs)
- Ambient Water Quality Criteria
- Ohio River Criteria

The ARARs for each contaminant of concern are summarized in Table 4-1.

In accordance with the Safe Drinking Water Act, the EPA has established MCLs and MCLGs for a number of contaminants. By definition, the MCLGs are nonenforceable health goals, while the MCLs are the enforceable standards which must be set as close to MCLGs as is feasible. The MCLs combine health effects information on specific contaminants with other inputs on exposure, methods for chemical analysis, methods of waste treatment, economics, etc. The total environmental exposure of a human to a specific contaminant is considered in developing the MCL, which attempts to set lifetime limits at the lowest practical level to minimize the amount of toxicant contributed by drinking water. A daily intake of two liters of water is assumed in developing these regulations.

Ambient water quality criteria for contaminants in surface waters are derived for the protection of aquatic life and for the protection of human health from the ingestion of contaminated water and/or organisms. Two criteria are derived for the protection of freshwater aquatic life (if adequate data are available): the "acute" criterion which represents the maximum concentration allowed at any time and the "chronic" criterion which represents the maximum 24-hour average concentration allowed.

The ambient criteria for the protection of human health from the toxic properties of a contaminant from ingestion of contaminated water and organisms assumes a daily ingestion of two liters of water and 6.5 grams of potentially contaminated fish products. The criterion for ingestion of contaminated organisms only assumes a daily ingestion of 6.5 grams of potentially contaminated fish products.

Ambient concentrations corresponding to several incremental lifetime cancer risk levels have been estimated for those contaminants which exhibit carcinogenic and/or mutagenic effects in laboratory tests and are, therefore, suspected of being potentially carcinogenic to humans. The ambient

TABLE 4-1 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Indicator Chemical	Ambient Water Quality Criteria (for Protection of Human Health), mg/L				Ambient Water Quality Criteria for Protec. of Fresh Water		State of Ohio River Criteria, mg/L	
	Drinking Water, mg/L		For Tox. Protection		For Carcin. Protec.			
	MCLG	MCL	Ingesting Water and Organisms Only	Ingesting Water and Organisms Only	Ingesting Organisms Only	Acute		
Chromium	0.12 (a)	0.05	-	-	-	0.016	0.011	0.05
Copper	1.3 (a)	-	-	-	-	9.2 x 10 <sup>-3</sup>	6.5 x 10 <sup>-3</sup>	0.034
Cyanide (Total)	-	-	0.2	-	-	0.022	5.2 x 10 <sup>-3</sup>	0.025
Fluoride	-	1.4-2.4	-	-	-	-	-	1.0
Phenol	-	-	3.5	-	-	-	-	0.01
Benzo(a)anthracene	-	-	-	-	2.8 x 10 <sup>-6</sup>	3.11 x 10 <sup>-5</sup>	-	-
Benzo(b+k)fluoranthene	-	-	-	-	2.8 x 10 <sup>-6</sup>	3.11 x 10 <sup>-5</sup>	-	-
Benzo(a)pyrene	-	-	-	-	2.8 x 10 <sup>-6</sup>	3.11 x 10 <sup>-5</sup>	-	-
Chrysene	-	-	-	-	2.8 x 10 <sup>-6</sup>	3.11 x 10 <sup>-5</sup>	-	-
Pyrene	-	-	-	-	2.8 x 10 <sup>-6</sup>	3.11 x 10 <sup>-5</sup>	-	-
Total PAHs	-	-	-	-	2.8 x 10 <sup>-6</sup>	3.11 x 10 <sup>-5</sup>	-	-

(a) Proposed value.

concentrations which may result in one excess cancer case per one million persons (i.e., risk =  $10^{-6}$ ) from the ingestion of contaminated water and organisms or the ingestion of contaminated organisms alone are presented in this section as ambient criteria for carcinogenic contaminants.

These guidelines (i.e., MCLGs, MCLs, ambient water quality criteria) were derived for the protection of human health from the ingestion of drinking water. The individual values for a given contaminant may vary due to the selection of different experimental studies as the basis for the calculations, different exposure periods and derivation for different purposes (i.e., MCLs take into account the economic feasibility of required waste treatment methods).

The Ohio River Valley Water Sanitation Commission recommendations presented are the minimum conditions applicable to all waters at all times and at all places for the main stem of the Ohio River.

Three values that describe the degree of toxicity posed by a chemical have been developed for use in the Superfund public health evaluation process (USEPA 1986c). They are:

- The acceptable intake for subchronic exposure (AIS)
- The acceptable intake for chronic exposure (AIC)
- The carcinogenic potency factor (for potential carcinogenic effects only)

The values are empirically derived and have not been adjusted for any site-specific conditions. The AIS and AIC values are derived from quantitative information available from animal studies or observations in human epidemiological studies on the relationship between intake and noncarcinogenic toxic effects. Sensitive populations are considered in the derivation. The carcinogenic potency factor (CPF) is the lifetime cancer risk per mg/kg body weight/day (the slope of the dose-response curve). Table 4-2 presents critical toxicity values including EPA's weight-of-evidence classification for potential carcinogens.

#### 4.1 Chromium

Chromium exists in the environment in three principal states: elemental Cr; trivalent,  $\text{Cr}^{+3}$ ; and hexavalent,  $\text{Cr}^{+6}$ . Compounds of  $\text{Cr}^{+6}$  are generally more toxic than  $\text{Cr}^{+3}$  compounds because they are more soluble, readily traverse biological membranes and have strong oxidizing properties. Detrimental effects from long-term ingestion of low levels of chromium in drinking water have not been observed. Sprague-Dawley rats administered water containing a series of doses up to 25 mg Cr/L either as chromium chloride ( $\text{Cr}^{+3}$ ) or as potassium chromate ( $\text{Cr}^{+6}$ ) for one year exhibited no pathological effects (MacKenzie et al. 1958). Female dogs administered 0.45 to 11.2 mg Cr/L, as potassium chromate ( $\text{Cr}^{+6}$ ), in their drinking water for four years showed no abnormalities in physical condition, food consumption or growth rate (Anwar et al. 1961). Chronic ingestion of water containing 1 mg/L of  $\text{Cr}^{+6}$  over a three-year period did not produce any adverse health effects in a Long Island family drinking from a private well (Davids and Lieber 1951).



TABLE 4-2 CRITICAL TOXICITY VALUES FOR CONTAMINANTS OF CONCERN

Chemical	Oral			Inhalation		
	Acceptable Intakes, mg/kg/day		Cancer Potency Factor, mg/kg/day <sup>-1</sup>	Acceptable Intakes, mg/kg/day		Cancer Potency Factor, mg/kg/day <sup>-1</sup>
	AIS <sup>(a)</sup>	AIC <sup>(b)</sup>		AIS	AIC	
Chromium (VI)	$2.50 \times 10^{-2}$	$5.00 \times 10^{-3}$	-	-	-	$4.10 \times 10^{+1}$ (A) <sup>(c)</sup>
Cyanides	-	$2.00 \times 10^{-2}$	-	-	-	-
Copper	$3.70 \times 10^{-2}$	$3.70 \times 10^{-2}$	-	-	$2.00 \times 10^{-2}$	-
Fluoride	-	$6.00 \times 10^{-2}$	-	-	-	-
Phenol	$1.00 \times 10^{-1}$	$1.00 \times 10^{-1}$	-	$1.90 \times 10^{-1}$	$2.00 \times 10^{-2}$	-
Benzo(a)anthracene	-	-	$1.15 \times 10^1$ (B2)	-	-	- (B2)
Benzo(b)fluoranthene	-	-	$1.15 \times 10^1$ (B2)	-	-	- (B2)
Benzo(k)fluoranthene	-	-	$1.15 \times 10^1$ (D)	-	-	- (D)
Benzo(a)pyrene	-	-	$1.15 \times 10^1$ (B2)	-	-	6.11 (B2)
Chrysene	-	-	$1.15 \times 10^1$ (B2)	-	-	- (B2)
Pyrene	-	-	$1.15 \times 10^1$	-	-	-

(a) AIS - Acceptable Intake for Subchronic Exposures.

(b) AIC - Acceptable Intake for Chronic Exposures.

(c) EPA's Weight-of-Evidence Rating. B2 - Probable Human Carcinogen (sufficient evidence of carcinogenicity in animals, inadequate evidence in humans), D - Not Classified (Inadequate evidence of carcinogenicity in animals), A - Human Carcinogenic (Sufficient evidence from epidemiological studies to support a causal association between exposure and cancer).

Source: USEPA 1986c

The major chronic effect of chromium is on the respiratory system. Effects include ulceration and perforation of the nasal system, chronic rhinitis and pharyngitis. Incidence of these effects are quite high, up to 80 percent, for occupationally exposed workers. Chromium has also been demonstrated to be a respiratory carcinogen in man. Evidence gathered since the 1950s has demonstrated that the incidence of respiratory cancer among those occupationally exposed significantly exceeds expected values. No evidence has been found to associate cancer and chromium at any other site than the lungs (USEPA 1980a).

Acute aquatic data indicate that invertebrate species are more sensitive than most fish to hexavalent chromium. Chronic toxicity values for trout were 265 µg/L and 1,990 µg/L for the fathead minnow. Additionally, other effects reported to be produced by hexavalent chromium included root weight inhibitions in blue-green algae, reduced growth in salmon and reduced life span and fecundity in Daphnia. One report on bioconcentration indicated a factor of one in rainbow trout. For trivalent chromium, water hardness affects toxicity, Cr<sup>+3</sup> being more toxic in soft water (USEPA 1980a).

#### 4.2 Copper

Acute exposure of humans to copper at doses of 0.005-7.6 g Cu causes nausea, vomiting, diarrhea, dizziness, headache, abdominal pain and, in some cases, death (USEPA 1984a).

Copper is an essential nutrient and the National Academy of Sciences (NAS) Food and Nutrition Board estimates on adequate and safe intake of about 2 to 3 mg/day (NAS 1980). Chronic ingestion of copper at this level should not be toxic to normal humans. However, those suffering from Wilson's Disease, an inherited autosomal recessive disorder of copper metabolism, may suffer from copper toxicity even at normal levels of copper ingestion (USEPA 1984a, NAS 1977, 1980). Copper accumulates in the liver of an affected person and causes symptoms including tremors, incoordination, anemia, jaundice, behavioral abnormalities and, eventually, death (USEPA 1984a).

Most animals absorb copper poorly from the gastrointestinal tract (NAS 1980), but sheep are a notable exception especially sensitive to toxicity due to copper (USEPA 1984a).

Occupational inhalation exposure to copper may cause dyspnea, weakness, anorexia or metal fume fever (USEPA 1984a).

Teratogenic effects of copper exposure were noted in studies on several animal species (mice, rats, lambs, guinea pigs). The levels of copper producing these effects were sometimes considerably higher than those that resulted in toxic effects in pigs (USEPA 1984a). No reports of teratogenic effects in humans due to copper exposure were located in the available literature.

Copper does not appear to be carcinogenic or mutagenic (USEPA 1984a, 1985a).

Aquatic organisms are susceptible to toxic effects of copper. Mean acute toxicity values range from 16.74 to 10,240  $\mu\text{g/L}$  for species in 41 generations of freshwater animals at a hardness of 50  $\text{mg/L CaCO}_3$ . Data indicate that acute toxicity decreases as hardness increases. Chronic toxicity values for 15 freshwater species range from 3.9 to 60.4  $\mu\text{g/L}$ , with fish and invertebrate species being about equally sensitive (USEPA 1986b).

#### 4.3 Cyanide

Cyanides are highly toxic by all routes of exposure (USEPA 1985a). Acute exposures in humans result in rapid breathing, gasping, tremors, convulsions and death, usually occurring within 20 minutes of ingestion of a fatal dose. The fatal oral dose for humans ranges from 0.7 to 2.9  $\text{mg CN}^-/\text{kg bw}$  (USEPA 1987). The acute oral  $\text{LD}_{50}$  for potassium cyanide is 4  $\text{mg CN}^-/\text{kg}$  in rats and 3.4  $\text{mg CN}^-/\text{kg}$  in mice (USEPA 1987). The toxicity of cyanide varies among species; a dose equal to the  $\text{LD}_{50}$  in mice had only minimal effects on guinea pigs (USEPA 1987).

Chronic exposure to cyanide in occupationally exposed individuals has been reported to cause toxic effects, including headaches, dizziness and thyroid enlargement. Animal studies have reported toxic effects of chronic cyanide exposure in several species. Weanling rats fed a diet providing about 30  $\text{mg CN}^-/\text{kg bw/day}$  for 11.5 months had significantly reduced body weight gain, decreased thyroxin secretion rates, increased thiocyanate excretion and vacuolization and myelin degeneration in the spinal cord (USEPA 1987).

Pigs fed diets containing 30.3, 276.6 or 520.7  $\text{mg CN}^-/\text{kg}$  diet throughout gestation and lactation showed hyperplasia of kidney glomerular cells and morphological changes in thyroid follicular cells. Dogs dosed with a capsule containing about 0.27  $\text{mg CN}^-/\text{kg bw}$  once a day for 16 months had degenerative changes in ganglion cells of the central nervous systems; however rats fed a diet which provided about 3.6 to 10.8  $\text{mg CN}^-/\text{kg bw/day}$  showed no clinical or histological effects. Increased thiocyanate levels were noted in blood and tissue samples (USEPA 1987).

Oral administration of cyanide has not been reported to cause teratogenic effects (USEPA 1987, 1984b). Cyanide has not been found to be mutagenic and no data on the carcinogenic effects of cyanide have been located in the available literature (USEPA 1984b, 1985a, 1987).

The acute toxicity values for a wide variety of freshwater species range from 44.7  $\mu\text{g/L}$  to 2,490  $\mu\text{g/L}$ , measured as free cyanide (the sum of cyanide present as  $\text{HCN}$  and  $\text{CN}^-$ ). All the species with acute values above 400  $\mu\text{g/L}$  were invertebrates. Chronic values for freshwater fish ranged from 7.85 to 16.4  $\mu\text{g/L}$  and chronic values for two invertebrate species were 18.3 and 34.1  $\mu\text{g/L}$ . Freshwater plants showed toxic effects at cyanide concentrations of 30 to 26,000  $\mu\text{g/L}$  (USEPA 1986b).

#### 4.4 Fluoride

The acute toxic effects of ingested fluoride on humans include nausea, vomiting, convulsions, coma and death. The lethal dose is dependent upon age and ranges from 32 to 64  $\text{mg F}^-/\text{kg bw}$  (USEPA 1985a).

While fluoride is not considered an essential nutrient, its value in preventing dental caries is well established. The maximum reduction in caries may occur at drinking water fluoride levels ranging from 2 to 4 mg/L (USEPA 1985c), but it has been suggested that the optimum level to maximize caries prevention and minimize adverse effects is about 1 mg/L (USEPA 1985c). The main adverse effect of fluoride at these levels (1 to 4 mg/L) is dental fluorosis, marked by discoloration, mottling and pitting of the teeth.

According to the USEPA (1985d) this effect is not an adverse health effect, but an adverse cosmetic effect, and fluoride in drinking water has been regulated accordingly. Dental mottling and tooth structure changes may occur in children exposed to fluoride in drinking water at levels greater than 0.6 to 1.3 mg/L, depending on diet and ambient temperature (NAS 1980).

Crippling skeletal fluorosis is an adverse health effect of daily exposure to 20 to 80 mg/day of fluoride over a period of 10 to 20 years or more (NAS 1980, USEPA 1985c). Other effects of exposure to high levels of fluoride include osteosclerosis, kidney damage, rheumatic attack, pain and stiffness (USEPA 1985c). Reported effects of fluoride which have not been found to be scientifically supportable include Down's Syndrome, cancer and allergic effects (USEPA 1985c). A rat and mouse bioassay to determine the oncogenic potential of fluoride exposure is currently underway.

Fluoride has not been consistently found to be mutagenic or teratogenic in human epidemiological studies (NAS 1977).

No data were found in the available literature on the effects of fluoride on aquatic organisms.

#### 4.5 Phenol

The toxic effects of phenol following acute oral exposure in humans include nausea, vomiting, central nervous system depression, respiratory failure and circulatory collapse. Doses of 10 to 30 g may be lethal (USEPA 1980b). Necrosis of mucous membranes of the throat and myocardial degeneration and necrosis were observed in animals following acute exposure at unspecified doses. Bronchopneumonia and purulent bronchitis resulted from severe inhalation intoxication (USEPA 1980b).

Adverse effects from long-term ingestion of phenol include reduced growth rates and infertility (USEPA 1980b). Rats administered phenol (800 to 2,400 mg/L) in drinking water for 12 months exhibited weight loss at the highest dose tested. When rats were fed phenol (100 to 1,200 mg/L) in the drinking water over two to five generations, growth was retarded and fertility was impaired. In another study, phenol administered in water at 100 to 5,000 mg/L over three to five generations was without adverse effect. No studies were found in the available literature on the teratogenic, mutagenic or carcinogenic potential of phenol resulting from oral ingestion.

Acute aquatic data for phenol indicate that certain fish and invertebrate species are adversely affected (USEPA 1980b). Cladocerans were the most sensitive invertebrate species, of which the young Daphnia magna was the most

sensitive (7,000 µg/L). Values for fish species range from 67,500 µg/L for fathead minnows to 5,020 µg/L for juvenile rainbow trout. Reported bioconcentration factors of 1.2 to 2.3 for goldfish suggest that no residue problem should occur from exposure to phenol.

#### 4.6 Polycyclic Aromatic Hydrocarbons

The PAHs are easily absorbed by all means of exposure. Degradation of PAHs forms potentially toxic by-products, epoxides, which are suspected to be the ultimate carcinogens. The PAHs are readily metabolized and eliminated in most species. Acute toxicity data are limited for man. In animal studies, it has been found that PAHs inhibit cells' normal mitotic cycle and suppress the immune system. Toxicity of individual PAH compounds is dependent on their structure (alkyl substitution). Acute toxicity of most PAHs is low (Clayton and Clayton 1983).

The most prominent effect of chronic exposure to some PAHs is tumor formation. Benzo(a)pyrene has been demonstrated to induce bronchial carcinoma in humans, although contributing factors such as smoking and environmental conditions need to be taken into account. Mutagenic tests have yielded positive results with certain compounds, most notably, benzo(a)pyrene. It has been shown that this compound crosses the placenta inducing cancer transplacentally. Other PAH compounds induce teratogenic and reproductive effects in laboratory animals (USEPA 1980c).

Limited data exist on the acute or chronic toxicity of PAH compounds to freshwater aquatic life. Bioconcentration is the only aspect which has been investigated. Freshwater invertebrate species can bioaccumulate benzo(a)pyrene up to 130,000 for short exposure periods. However, PAH compounds are readily metabolized and eliminated and are not considered persistent pollutants.

Plants will take up PAH compounds in the soil and translocate them to shoots. Surface absorption from deposition on shoots and fruits can be a major bioaccumulation route. Only ten percent of benzo(a)pyrene absorbed in this manner can be removed by cold water washing (USEPA 1980c).

## 5.0 RISK AND IMPACT EVALUATION

### 5.1 Human Health

The potential exposure pathways of concern identified in Section 3.3 are:

- On-site ingestion of and associated direct contact with contaminated ground water (including ingestion of water from the CAC well if interceptor wells cease pumping)
- On-site inhalation of particulates from on-site soils
- Direct contact with on-site soils
- Off-site ingestion of and dermal contact with surface water
- Off-site ingestion of ground water
- Off-site inhalation of particulates from on-site soils
- Inhalation of volatiles from ground water
- Inhalation of volatiles from surface water
- Inhalation of volatiles from soils
- Ingestion of contaminated fish

In the absence of rigorous quantitative risk assessments, the contaminant risk is assessed in two ways in accordance with the guidelines contained in the Superfund Public Health Evaluation Manual (USEPA 1986b). First, the exposure point concentrations in various media are compared to "applicable or relevant and appropriate requirements" (Table 4-1). The resultant ratio (exposure level/acceptable level) is not a quantitative measure of the incidence or severity of effects, but is a numerical indicator of the transition between acceptable and unacceptable exposure levels. Any ratio greater than 1.0 indicates an unacceptable exposure level.

Next, chronic and subchronic chemical intakes are calculated from exposure point concentrations and standard intake values. Noncarcinogenic risks are assessed by calculating a hazard index which is the ratio of human intake to acceptable chronic and subchronic intakes. These hazard indices are then summed to provide a total hazard index. This assumption, that the adverse effect is proportional to this sum is consistent with EPA's risk assessment guidelines for chemical mixtures (USEPA 1986a). Anytime the index exceeds unity there may be a concern for a potential health risk under the specified exposure conditions.

In the case of carcinogens such as the PAHs there are no acceptable daily intakes. Instead, estimated daily intakes are multiplied by the cancer potency factor ( $11.5 \text{ (mg/kg/day)}^{-1}$ , Table 4-2) to give an upper-bound lifetime cancer risk for that exposure route. Alternatively, ambient concentrations can be compared to that carcinogen concentration that would produce an incremental lifetime risk of  $10^{-6}$ . The comparison is appropriate for individual PAHs or for PAHs in combination (total PAH). Only the ingestion of ground water and Ohio River water can be completely analyzed in this fashion.

Three exposure pathways are complete enough to perform these kinds of risk measurements. These pathways are: possible ingestion of contaminated ground water on-site (Table 5-1), possible ingestion of or contact with (since State of Ohio standards for the Ohio River do not specify water use) contaminated Ohio River water (Table 5-2) and direct contact with on-site soils (Table 5-3).

For potential ground-water and surface-water exposure via drinking water, the most appropriate comparison values are MCLs and MCLGs from the Safe Water Drinking Act (Table 4-1). Ratios of ambient concentrations to these values are presented in Tables 5-1 and 5-2. State of Ohio standards and Ambient Water Quality Criteria ratios are included for Ohio River surface water. The federal drinking water standards and criteria are based on lifetime exposures, so it is most appropriate to use a ratio of long-term water concentration to the standard or criterion. In the absence of more data on which to construct models of the time history of fate and transport of contaminants at the site, the current concentrations are used. The maximum value encountered is the upper-bound estimate and the mean value is taken as the best estimate for concentrations in Table 3-1. The upper-bound estimate was used only to calculate subchronic daily intakes; the best (mean) estimate was used for all other ratio calculations. In cases where there was only one sample, these values are the same. Note, therefore, that this analysis assumes that current concentrations will be maintained for a lifetime; or in other words, that material emplaced in the 1970s will continue to be released at current rates and environmental fate will be unchanged. At the present time workers at the Ormet and CAC facilities do not consume contaminated ground water. The risk is only a potential one that would eventuate if the interceptor wells are not pumped at current rates. Finally, the use of Ohio River water by downstream populations is unknown, so that ratios based on drinking water standards may be inappropriate.

Chronic daily intakes are calculated using the guidelines in USEPA (1986b). For drinking water it is assumed that an average 70-kg adult drinks an average 2 liters of water per day. Thus, the estimated human intake value for drinking water is 0.029 L/kg/day. To calculate the ratios in Table 5-1 and 5-2, the appropriate exposure point concentration is multiplied by the intake value and divided by either the AIS or AIC value.

Keeping these assumptions and caveats in mind, chromium, copper, cyanide and fluoride are at unacceptable levels (some ratio greater than one) in on-site ground water, and that cyanide and PAHs are at unacceptable levels in Ohio River surface water. Chromium, copper, and phenol concentrations in Outfall 004 exceed State of Ohio standards for the river, but outfall water fully diluted by river water does not. These contaminants may however be at unacceptable levels in the mixing zone of the river just downstream of the plant.

The same is done for Ohio River water, assuming that it is used for drinking. If there is only incidental ingestion, the ratios, already less than one, would be even smaller. The total chronic hazard index (sum of the individual chronic hazard indices) for hypothetical ground water ingestion is 65.51; for surface water it is only 0.11.

Subchronic daily intakes were calculated in the same way, except that the upper-bound (maximum) contaminant concentration was used instead of the mean concentration. The total subchronic hazard index for hypothetical ground-water contamination is 1.15; for Ohio river surface water it is only  $6.9 \times 10^{-5}$ .

TABLE 5-1 RATIO OF ON-SITE GROUND-WATER EXPOSURE POINT  
CONCENTRATIONS TO ARARs AND CRITICAL TOXICITY VALUES

Contaminant	Exposure Level; Acceptable Level <sup>(a)</sup>	Hazard Index	
		Subchronic <sup>(b)</sup>	Chronic <sup>(c)</sup>
Chromium	1.0	0.15	0.29
Copper	0.31	1.0	0.31
Cyanide	-	-	16.8
Fluoride	42.1-72.1	-	48.1
Phenol	-	$8.7 \times 10^{-4}$	0.01
PAHs	-	(d)	(d)
Total Hazard Index:		1.15	65.51

- (a) Calculated by dividing the best estimate exposure point concentration for on-site ground water for each chemical (Table 3-1) by the appropriate MCL or MCLG (Table 4-1).
- (b) Calculated by multiplying the upper-bound exposure point concentration for on-site ground water (Table 3-1) by 0.029 L/kg/day and dividing by the appropriate Acceptable Intake for Subchronic Exposure (AIS) from Table 4-2.
- (c) Calculated by multiplying the best estimate exposure point concentration for on-site ground water for each chemical (Table 3-1) by 0.029 L/kg/day and dividing by the appropriate Acceptable Intake for Chronic Exposure (AIC) from Table 4-2.
- (d) No acceptable intake for potential carcinogens.



TABLE 5-2 RATIO OF OHIO RIVER WATER EXPOSURE POINT CONCENTRATIONS (EPCs)  
TO ARARS AND CRITICAL TOXICITY VALUES

Contaminant	EPC: MCL Drinking Water (b)	EPC: Ohio River Criteria (c)	EPC: Ambient Water Quality Criteria (a)			Hazard Index	
			For Toxicity Protection of Human Health	For Carcinogenicity Protection of Human Health	For Aquatic Life Protection	Subchronic (d)	Chronic (e)
Chromium	$3.0 \times 10^{-4}$	$3.0 \times 10^{-4}$	$3.0 \times 10^{-4}$	-	$9.5 \times 10^{-4}$	$2.2 \times 10^{-5}$	$8.8 \times 10^{-5}$
Copper	0.01	$4.5 \times 10^{-4}$	-	-	$1.7 \times 10^{-3}$	$1.5 \times 10^{-5}$	$1.2 \times 10^{-5}$
Cyanide	-	2.8	0.4	-	3.2	-	0.10
Fluorides	0.005-0.009	0.01	-	-	-	-	0.01
Phenol	-	$9.8 \times 10^{-4}$	$2.8 \times 10^{-6}$	-	-	$3.2 \times 10^{-5}$	$2.8 \times 10^{-5}$
PAHs							
Benzo(a)anthracene	-	-	-	2.8	-	-	-
Benzo(b+k)fluoranthene	-	-	-	5.7	-	-	-
Benzo(a)pyrene	-	-	-	1.3	-	-	-
Chrysene	-	-	-	5.7	-	-	-
Pyrene	-	-	-	6.8	-	-	-
Total PAHs	-	-	-	22.5	-	-	-
Total Hazard Index:						0.11	$6.9 \times 10^{-5}$

- (a) Calculated by dividing the best estimate exposure point concentration from Table 3-1 for Ohio River surface by the ambient water quality criteria from Table 4-1.
- (b) Calculated by dividing the best estimate exposure point concentration (Table 3-1) by the appropriate MCL or MCLG (Table 4-1).
- (c) Calculated by dividing the best estimate exposure point concentration for Ohio River surface water (Table 3-1) by the appropriate Ohio River Criteria.
- (d) Calculated by multiplying upper-bound exposure point concentration for Ohio River surface water (Table 3-1) by 0.029 L/kg/day and dividing by the appropriate AIS critical toxicity value (Table 4-2).
- (e) Calculated by multiplying the best estimate exposure point concentration for Ohio River surface water (Table 3-1) by 0.029 L/kg/day and dividing by the appropriate AIC critical toxicity value (Table 4-2).

TABLE 5-3 RATIO OF DISPOSAL POND SEDIMENT EXPOSURE POINT  
CONCENTRATIONS TO CRITICAL TOXICITY VALUES

Contaminant	Hazard Index	
	Subchronic <sup>(a)</sup>	Chronic <sup>(b)</sup>
Chromium	0.02	0.04
Copper	0.15	0.07
Cyanide	-	0.03
Fluoride	-	0.001
Phenol	$8.7 \times 10^{-6}$	$5 \times 10^{-4}$
Total Hazard Index:	0.17	0.14

- (a) Calculated by multiplying the upper bound exposure point concentration from Table 3-1 for disposal pond soil by  $5.09 \times 10^{-6}$  kg soil/kg/day and dividing by the appropriate AIS value from Table 4-2.
- (b) Calculated by multiplying the best estimate exposure point concentration from Table 3-1 for disposal pond soil by  $5.09 \times 10^{-6}$  kg soil/kg/day (the human intake value for soil) and dividing by the appropriate AIC value from Table 4-2.

For the carcinogenic PAHs, there are no acceptable daily intakes, but multiplying chronic daily intakes in mg/kg/day by the cancer potency factor for oral intake of PAHs (Table 4-3) yields the incremental lifetime cancer risk associated with ingestion of PAHs. Individual contaminants are summed, so that the total risk due to PAH ingestion can be obtained. Total risk can also be estimated by using the "total PAH" values in Table 3-1. Total PAH risk from ground-water ingestion is:

$$11.5 \text{ (mg/kg/day)}^{-1} \times (0.166 \text{ mg/L} \times 2 \text{ liters/day}) / 70 \text{ kg} = 5.5 \times 10^{-2}$$

For Ohio river water the cancer risk from chronic ingestion is  $2.1 \times 10^{-5}$ . The generally accepted range for total upper-bound excess cancer risk is  $1.0 \times 10^{-4}$  to  $1.0 \times 10^{-7}$  (USEPA 1986a).

To determine the potential endangerment posed by direct contact with on-site soils, a comparison was made between the chronic and subchronic acceptable intake values in USEPA (1986c) and calculated chemical intakes at the site (Table 5-3). The calculated chemical intake from exposure to on-site soils was estimated using the equation:

$$I = C_s \times IC \quad (3)$$

where:

I = on-site intake (mg/kg)  
 $C_s$  = soil concentration (mg/kg)  
 $IC$  = intake coefficient (kg/kg/day)

The intake coefficient for dermal exposure and incidental ingestion is from Hawley (1985), based on an assumed absorption of 2% from a soil matrix for an adult working on site 5 days/week for 50 weeks/yr. The intake coefficient is  $5.09 \times 10^{-6}$  kg soil/kg/day. Measured soil concentrations are found in Table 3-1. By this calculation and with these assumptions (including the assumption that the few samples collected are representative of the area and that the contaminants do not degrade) no contaminants are at unacceptable levels in disposal area soils. The chronic hazard index for disposal soil is 0.14; the subchronic hazard index is 0.17.

Cancer risk due to contact with PAHs in on-site soils is calculated in the same way as the cancer risk from ingestion of water

$$\text{Cancer risk} = \text{CPF} \times IC \times IF \quad (4)$$

where:

CPF = Cancer Potency Factor for PAHs  $(11.5 \text{ mg/kg/day})^{-1}$   
IC = soil concentration  
IF = intake factor for soil  $(5.09 \times 10^{-6} \text{ kg soil/kg/day})$

The total PAH risk from soil is  $1.5 \times 10^{-5}$  (maximum soil concentration) or  $7 \times 10^{-6}$  (mean soil concentration).

There are no monitoring data on air concentrations of contaminants to quantitatively evaluate endangerment due to inhalation of contaminants, and no data on wildlife population contaminant levels to calculate risks from ingestion of fish or wildfowl. Fish contaminant concentrations can sometimes be estimated from surface-water concentrations and fish bioconcentration factors. In this case this method may not be reliable for PAHs because of their rapid metabolism.

## 5.2 Environmental and Public Welfare

There are insufficient data on wildlife populations to know which, if any, are exposed. Risks could arise from contact with on-site soils, surface run-off or ponded water in the disposal area or from Ohio River surface water downstream of the Ormet site.

The major impact on socioeconomic risk is the potential decrease in value of property near the site and loss of income from future economic development due to loss of a pure, shallow aquifer. There is a potential loss of income from contamination of the Ohio River, which may experience loss of recreational use downstream of the Ormet plant.

There is also an additional cost to Ormet if public water needs to be brought into the plant because of well contamination including private wells that may become contaminated.

## 6.0 CONCLUSIONS

### 6.1 Potential for Endangerment

The three exposure pathways that are complete indicate potential endangerment to human health. These are: future on-site ingestion of contaminated drinking water, ingestion and/or contact with Ohio River water downstream of the plant from river mile 123 to river mile 162 and direct contact with on-site soils in the past disposal area.

Measured concentrations of chromium, copper, cyanide, and fluoride in on-site ground water are at unacceptable levels for ingestion, although this ground water is not now used as drinking water. Lifetime incremental cancer risk from hypothetical PAH ingestion of ground water is  $5.5 \times 10^{-2}$ . Estimated concentrations of cyanide and PAHs are at unacceptable levels in the Ohio River downstream of the plant. Lifetime incremental cancer risk from chronic ingestion of PAH-contaminated river water is  $2.1 \times 10^{-3}$ . In addition, phenol and fluoride concentrations in Outfall 004 are at unacceptable levels, which indicates potential endangerment in the river outfall mixing zone (three miles downstream of plant). The potential incremental lifetime risk from soil PAH contact (mean concentration) is estimated to be  $7 \times 10^{-6}$ .

Other exposure pathways are suspected, but the data required to complete them are unavailable. Of these, on-site inhalation of airborne particulates and off-site ingestion of contaminated ground water are suspected to be the most important because the site concentrations are high and the opportunities for dispersion and transformation are less than with other incomplete exposure pathways.

### 6.2 Uncertainties in Analyses

Except for cyanide and fluoride in ground water, this assessment is based on only a handful of priority pollutant analyses. No quality assurance/quality control results are available for the data that do exist. The chemical form in which the contaminants are present in water and soil are unknown. The size of the area contaminated and the variability of contamination in the disposal area are likewise unknown. The nature of sample treatment and preparation (for example, how or if the water samples were filtered) that may bear on the significance of reported concentrations are unknown. No on-site wind and soil erodibility data are available to estimate the importance of the airborne dust inhalation exposure pathway, and no off-site data on ground-water contaminant concentrations are available to estimate downgradient, off-site migration and ingestion pathways. The validity of the assumptions in estimating river concentrations (complete mixing, no other site-associated sources, ingestion of water) and soil intakes (site use, soil contact) is suspect. In the absence of data to the contrary, uncertain assumptions of continued release of contaminants from the disposal area at current rates and no degradation or transformation have been made. Size and demographic characteristics of exposed or potentially exposed human and wildlife populations are inadequately characterized.

### 6.3 Future Data Considerations

The following is a list of future data items to be considered for an adequate assessment of endangerment at the Ormet site:

- surface soil, atmosphere, ground-water concentrations of priority pollutants at the Ormet site and surrounding area
- surface runoff concentrations and frequency and volume of runoff
- on-site wind velocities and directions
- hydraulic connection of shallow aquifer with bedrock aquifer
- location of discharge zones of shallow and bedrock aquifer
- Ohio River water contaminant concentrations upstream and downstream of plant sufficient to model river mixing and transport
- vertical and horizontal variability of contaminants in the disposal area
- background (uncontaminated area) concentrations in soil, ground water, and surface water
- chemical form of contaminants of concern in ground water, especially pH dependency
- site specific volatility, solubility, sorption and retardation factors of contaminants of concern
- ground-water flow rates and dispersion coefficients
- ground water and surface water use patterns (drinking, irrigation, recreation) in the area
- likelihood of continued pumping of ground water at the interceptor wells
- potential for isolation or removal of disposal area soils
- wildlife population abundance and distribution near the plant; human use of these populations
- bioconcentration factors in wildlife

In addition, consideration of the required input to various models of contaminant release and transport in soils, air, ground water and surface water outlined in the Superfund Exposure Assessment Manual (Schultz et al. 1986) ought to be given before and during the collection of site data.

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